

CONTAMINATION EFFECTS STUDY

FINAL REPORT

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In-Situ Optical Surface Measurement Apparatus

1.0 Introduction

The In-Situ Optical Surface Measurement System is a facility designed to study the deleterious effects of particulate materials on the surface reflectivities of optical materials in the vacuum ultraviolet (VUV). This arrangement is designed to simulate the on-orbit effects of contamination and degradation of optical surfaces.

This simulation is accomplished through the use of non-coherent VUV sources illuminating optical surfaces located in a high vacuum vacuum chamber. Employing several sources of contamination the reflectivity is measured both at the specular reflection as well as at two scattered positions, forward and reverse.

The facility has been out of operation for a number of years and most of the information concerning the experimental equipment and electrical wiring has been lost. With that in mind this task has been concerned mostly with gathering the information and gaining the experience required to operate the system. In the following pages we will run through each piece of equipment used in the experiment, go through a series of steps to get the equipment up and running and also provide the operator some contacts to use if the going gets rough. Mixed in with the discussion will be some useful hints gleaned from the experience of this task period.

The experimental arrangement is shown schematically in figure 1. The chamber must be run at pressures below approximately 10^{-6} Torr to eliminate the absorption effects of air on the VUV wavelengths.

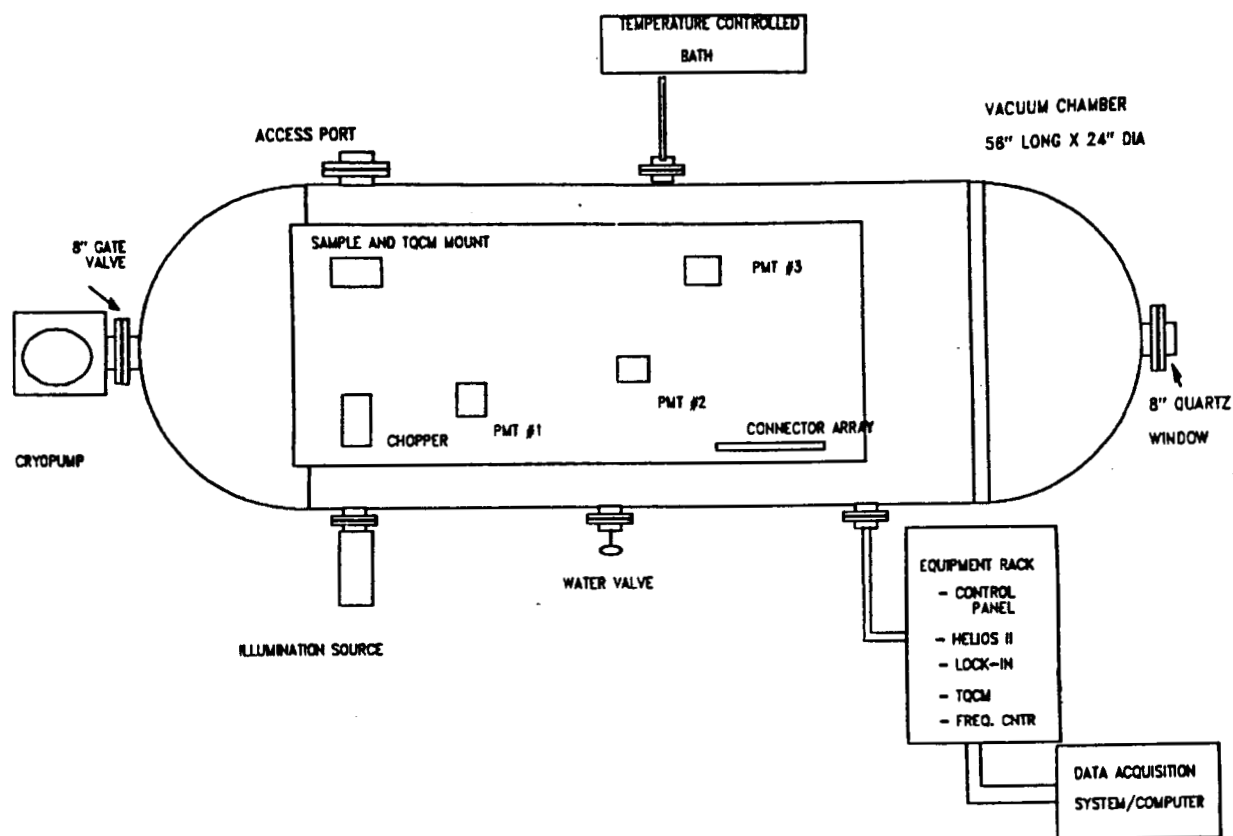


Figure 1. In-situ Optical Surface Measurement Apparatus

2.0 System Components

The system consists of the following components;

2.1. Vacuum system

- 2.1.1. Chamber
- 2.1.2. Roughing Pump
- 2.1.3. Cryopump
- 2.1.4. Valving and associated hardware

2.2. Electronics

- 2.2.1. Equipment rack
- 2.2.2. Vacuum feedthroughs
- 2.2.3. Internal connectors
- 2.2.4. Chopper system
- 2.2.5. Photomultipliers and their high voltage supplies
- 2.2.6. Temperature-Controlled Quartz Crystal Microbalance (TQCM)

2.3. Optical Train

- 2.3.1. Krypton RF discharge tubes
- 2.3.2. Collimating apertures
- 2.3.3. Sample mounts
- 2.3.4. Detector mounts
- 2.3.5. Detectors

2.4. Contamination Subsystem

- 2.4.1. Contaminant mount and heat source
- 2.4.2. Sample mount cooling system
- 2.4.3. Temperature-Controlled Quartz Crystal Microbalance (TQCM)

2.5. Data Acquisition

- 2.5.1. Telex AT compatible computer
- 2.5.2. Helios II computer front end
- 2.5.3. Software

2.1 Vacuum system

The experiment is housed almost entirely inside the system vacuum chamber. This section will discuss the procedures required to evacuate the chamber and prepare the system for operation. Figure 2 shows the block diagram of the hardware used in this system.

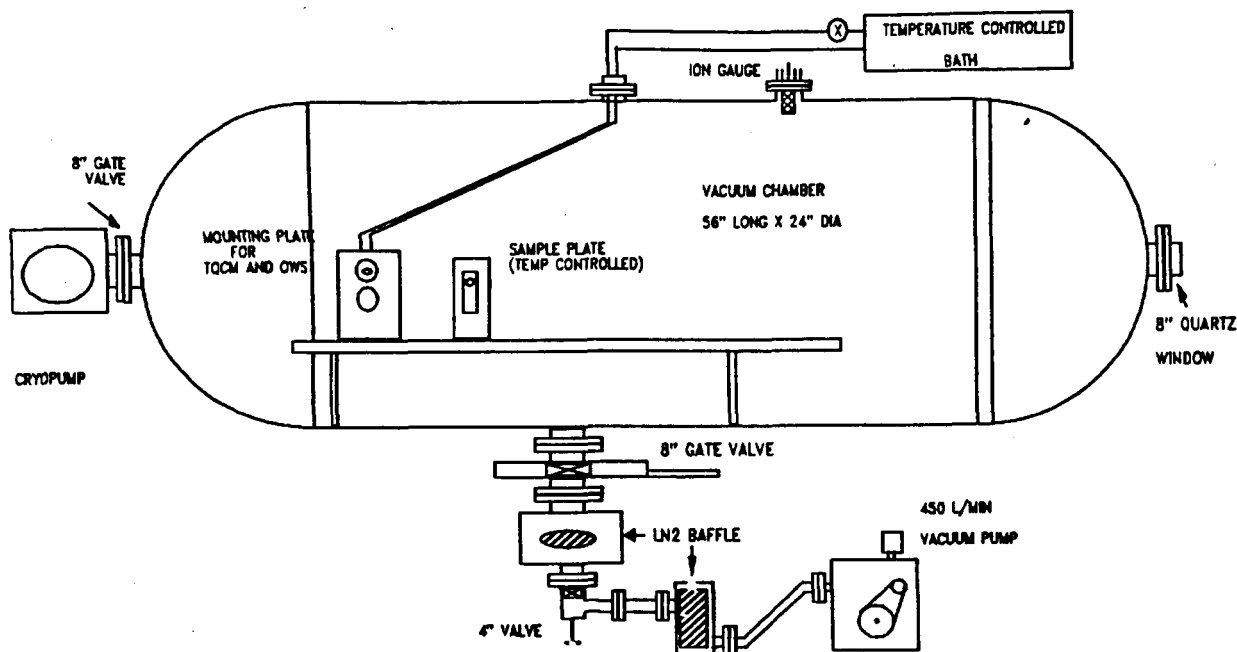


Figure 2. Block Diagram of Vacuum System

2.1 Chamber

The chamber is a cylinder approximately 24 inches in diameter and 48 inches long. This works out to be approximately 12.5 cubic feet in volume.

To pump out this volume we use two pumps. First we use a roughing pump to take the volume down to approximately 10 microns pressure and secondly we use a cryopump to further

reduce the pressure to the 10^{-6} or better range.

There are also various ports for physical as well as electrical and coolant access to the evacuated volume. See figure 2 for a block diagram of this layout.

2.2 Roughing pump

The roughing pump is a Welch Duo-Seal mechanical pump located on the floor directly underneath the rear of the chamber. This pump is isolated from the chamber, cryopump and other volumes by the use of two liquid nitrogen (LN2) cold traps. This is done to prevent backstreaming of pump oil during normal pumpdown of the system and associated parts. This pump should never be operated without the traps full of LN2.

2.3 Cryopump

For bringing the chamber down to operational pressures we use a Varian Cryostack 8 cryopump. This pump is bolted onto the rear of the chamber and is isolated by an eight (8) inch pressure actuated gate valve. This pump is an unvented, closed volume type pump where the gas removed stays in the pump. This means that the chamber pressure must be as low as the roughing pump can take it before the cryopump can be introduced to the system.

If the cryopump has been subjected to a large gas load or has been operating a long time the pumping action will be greatly reduced. Under these conditions the cryopump will need to be regenerated. The following subsection details how to regenerate the cryopump.

2.3.1 Regenerating the cryopump

Under normal operating circumstances the cryopump will "fill-up" and will require regeneration. This is a simple procedure and can be found in the operating manual for the particular pump. What follows is a short outline for doing this procedure.

1. From a warm start (warm cryopump).

If the cryopump has been off long enough to warm up to room temperature (say overnight) you can skip to step 3.

2. From a cold start (cold cryopump).

Turn off the cryopump. This starts warming up the pumping surfaces. Since the pump uses cold surfaces to produce pumping action, no regeneration can take

place before those surfaces are warmed to room temperature. Therefore you must warm up the pump. This is done by either turning off the pump and waiting until tomorrow or by opening the system to some buffer gas to warm the pumping surfaces.

Purge the cryopump with warm, dry nitrogen through the purge port on the pump head. Remember to open the relief valve to allow the nitrogen to escape.

Continue the purge for approximately 1 hour or until it appears the surfaces are warm. Do Not apply a heat source to the outside of the pump.

3. Turn on the roughing pump and be sure the LN2 traps are filled. This pump will remove gas that has been condensed out on the cryopumps pumping surfaces.
4. Make sure the purge and relief valves are securely closed and open the roughing port on the side of the pump head to pump down the head. This pump down should last approximately 2 hours.
5. When the cryopump head has pulled down to low pressure close the roughing valve.
6. Turn on the cryopump and wait for the temperature to fall to the operating range. This should take approximately 30 minutes.

The cryopump is now ready for normal operating loads.

2.4 Valving and Associated hardware

All valves except the relief valve located on the top left of the chamber are pressure actuated. The relief valve is a hand turned valve next to the thermocouple pressure gauge. Air pressure for these valves is supplied by building wide air supply lines. Our particular line enters the room on the west side of room E114. At this point there is a valve and regulator for controlling air pressure. For normal operation we typically need somewhere between 80 and 100 psi. Also located where the line enters the room is a bulb for removing condensed water from the air supply. The air system regularly comes with lots of water that will interfere with the cooling of the discharge tube so at these times it is recommended that you drain the bulb two or three times per day.

There is also a vacuum line running from the roughing pump to the front volume of the source mounting flange. This line is used to rough the discharge tube mounting volume when you change tubes or insert a filter or attenuator in front of the

discharge tube. This prevents a large pressure spike from entering the cryopump and vacuum chamber.

2.2 Electronics

The electronics consists mainly of home grown, personally built electrical work. Since all the important pieces of equipment are contained in the vacuum, we must provide vacuum feedthroughs for all the required electrical signals. Figure 3 shows the primary connections and wiring diagrams for this experiment.

SYNC SIGNAL OUTPUT

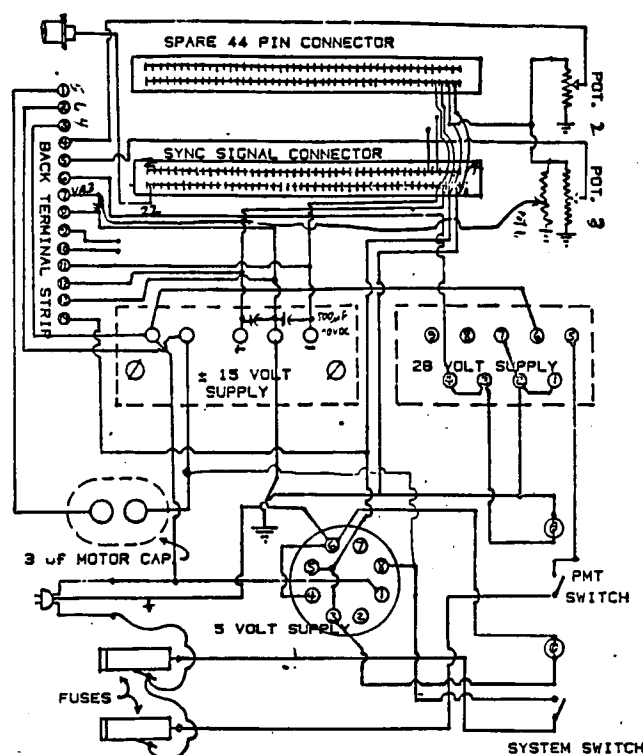


FIGURE 3 CONTROL BOX CIRCUIT LAYOUT

Figure 3. Control Panel Wiring Diagram

2.2.1 Equipment Rack

The major controlling components of this experiment are contained in the rack of equipment immediately adjacent to the vacuum chamber. This rack contains all the external electronics and provides for control of the PMT's and output to the data acquisition system.

Turn on/ turn off of the vacuum contained electronics is provided at the switch panel near the top of the equipment rack. This panel, depicted in figure 4 has three two pole switches on the right and three potentiometers on the left. Main power to the panel and power to the chopper is supplied by the rightmost switch. The middle switch is not used and the leftmost switch provides +28 vdc to the PMT high voltage supplies. The three pots control the gain of the three PMT's, backscatter, specular and forwardscatter, respectively.

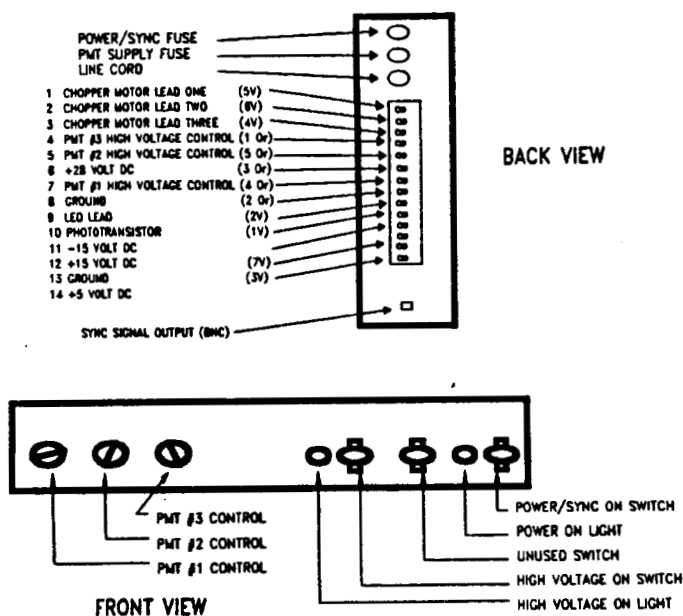


Figure 4. System Control Panel

This rack also contains the three lock-in amplifiers. They are from top to bottom connected to the backscatter, specular and forwardscatter PMT's. Output from these lock-ins is hardwired to the Helios computer front end (located immediately below the lower lock-in) and BNC cables are available to monitor the signals at the oscilloscope or strip chart recorder.

Also at the bottom of the rack is the TQCM controller and below that is a frequency counter to monitor the output frequency of the TQCM. This output is also hardwired to the Helios.

2.2.2 Vacuum Feedthroughs

Warning! The chopper uses 110 V, 60 cycle wall current. Turn off the power before servicing the interior of the chamber.

The required vacuum feedthroughs are pictured in figure 5. I have labeled these feedthroughs arbitrarily as #1 in the 9:00 O'clock position, #2 in the 3:00 O'clock position and #3 in the upper left position. These three feedthroughs provide all the signals to and from the vacuum required to operate this setup. Figure 6 shows the pin breakout for feedthrough #2 and #3. The #1 feedthrough only passes the evaporation and TQCM signals.

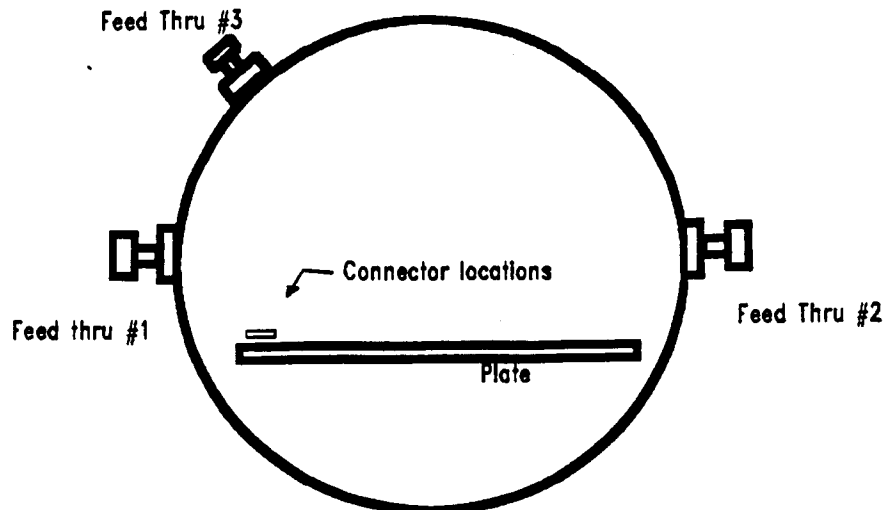
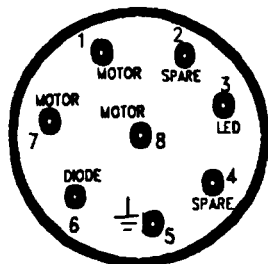


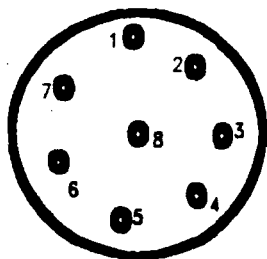
Figure 5. Vacuum Chamber/ End View

FEEDTHROUGH #3



PIN #	PIN # ON CONNECTOR #1
1	#5 MOTOR
2	SPARE
3	#2 LED
4	SPARE
5	#3 GROUND
6	#1 PHOTODIODE
7	#4 MOTOR
8	#6 MOTOR

FEEDTHROUGH #2



PIN #	PIN # ON #1 CONNECTOR	PIN ON EQUIPMENT RACK
1	17, 18, 19	(#7 ORANGE WIRE) EVAP SOURCE
2	-	- COMMON/SPARE
3	14	5 PMT 2 HV CONTROL
4	13	7 PMT 1 HV CONTROL
5	12	6 +28 VDC
6	11	8 GROUND
7	10	4 PMT 3 HV CONTROL
8	20, 21, 22	(#8 ORANGE WIRE) EVAP SOURCE

FIGURE 6 PINOUTS FOR FEEDTHROUGHS #2 AND #3

2.2.3 Internal Connectors

Figure 7 shows the block diagram of the equipment located on the plate inside the chamber. To provide electrical connection to the outside world there are two 22 pin edge connectors at the forward left side of the plate. Figure 8 shows the breakout of the two connectors. Connector #1 provides off plate communication while #2 is only for wiring on plate. Located in the storage cabinet is a couple of made up connectors that will allow you to patch from these connectors to the equipment rack to allow bench top operation of the equipment outside the vacuum chamber.

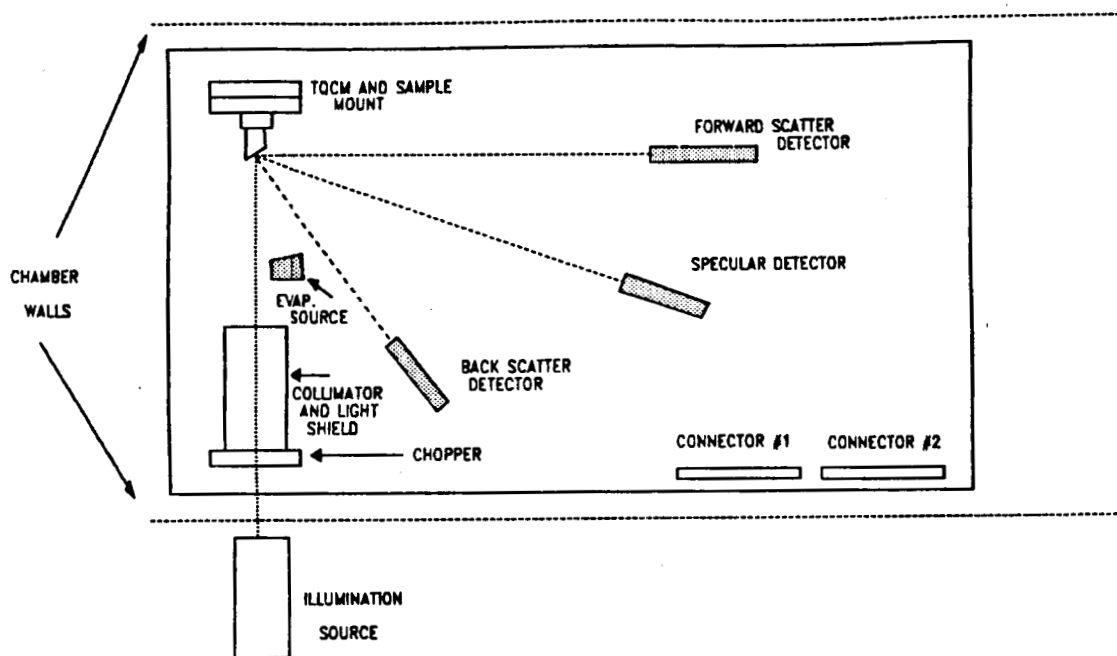


Figure 7. Arrangement of Equipment Inside Vacuum Chamber

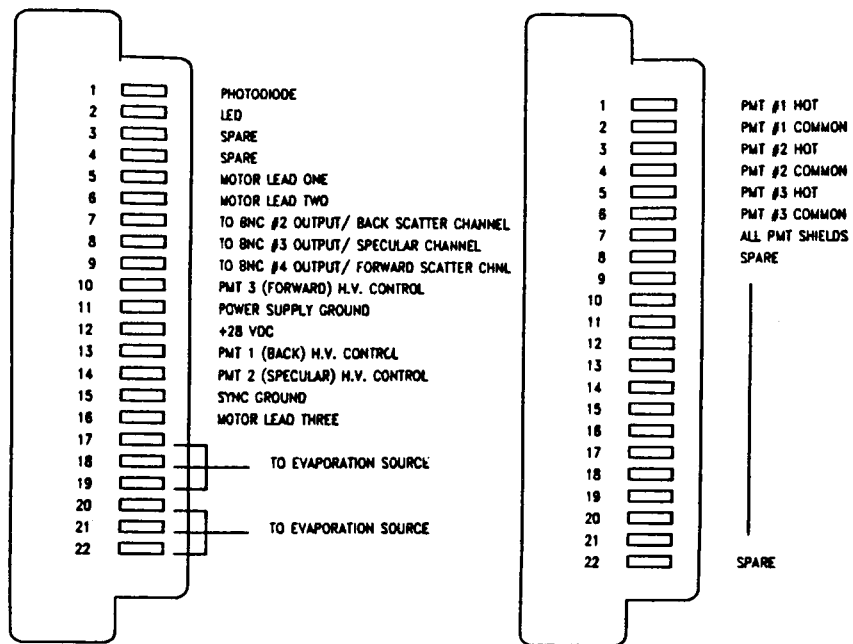


Figure 8. Connector Pin Assignments

2.2.4 Chopper System

The chopper is internal to the vacuum chamber and is operated by the on/off switch on the equipment rack. The purpose of the chopper is to chop the UV source illumination in order to allow synchronous detection using the lock-in amplifiers.

Do Not operate the chopper without cooling water. The water supply is turned on with the valve located on the left side middle next to the UV source.

The chopper reference signal is generated using the circuit shown in figure 9. The LED and photodiode are physically located around the chopper wheel using the same holes that the UV illumination passes through. Note that the LED operates in the infrared and the photodiode cuts off longward of the visible so that there is no stray light problems from the UV sources. This arrangement produces a reference square wave of 1 khz 2.8 volt peak-to-peak biased down by -15 volts (runs from -12.2 v to -15 v).

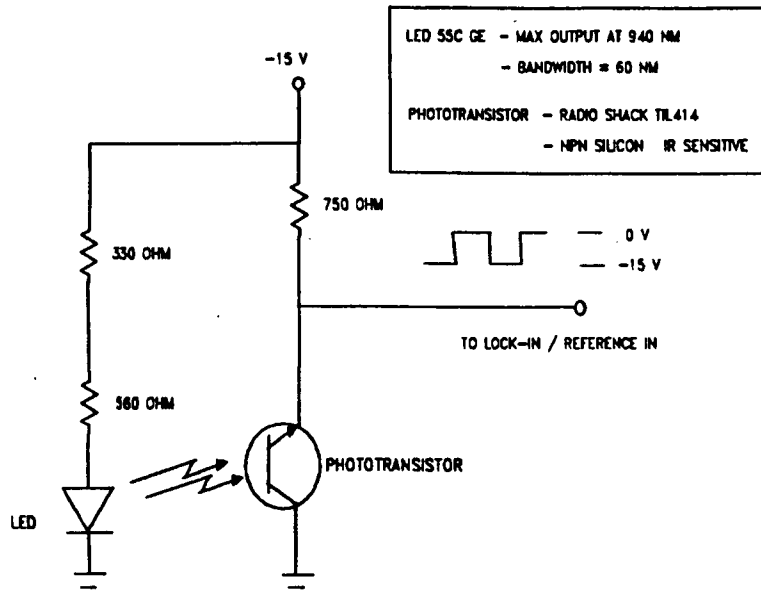


Figure 9. Chopper Reference Circuit

2.2.5 Photomultipliers and Their High Voltage Supplies

The photomultipliers are solar blind UV tubes supplied by EMR Photoelectric (see section 4.2). These tubes are 18 stage, end-on, magnesium fluoride window tubes with a 9.5 mm diameter, semi-transparent cesium telluride photocathode. The spectral sensitivity extends from 115 nm (mag-fluoride cutoff) to approximately 350 nm (photocathode threshold). The typical quantum efficiency is 6% at the Lyman alpha line and a typical room temperature dark current of 2×10^{-11} ampere at a gain of 10^6 . The original calibration curves are in the storage cabinet if you need them.

The high voltage supplies for these PMTs are vacuum compatible and are located on the plate in the chamber (see figure 7). As of the end of 1988 there was only one supply working so that you can only run one PMT at a time. You can switch between PMTs by turning off the high voltage and switching to another PMT with the two high voltage switches located on the table immediately to the lower left of the chamber. CAUTION!, the output of the high voltage supplies can reach 4 kilovolts so be careful.

The HV power supply is a +28 vdc input and up to 4 KV output depending on the 0-5 vdc input control voltage. This control voltage is supplied through the potentiometers located on the equipment rack. The numbering system is discussed in section 2.2.1.

2.2.6 Temperature-Controlled Quartz Crystal Microbalance (TQCM)

The controller for the TQCM is located in the equipment rack and is wired through feedthrough #1 straight to the TQCM head (note that the wires do not connect through connector #1 on the plate). In our application the TQCM is mounted above the sample in direct view of the evaporation source (approx. four inches away). A large brass heat sink is provided to stabilize temperatures. Also provided is tubing soldered to the heat sink containing coolant to maintain constant temps.

Also provided in the rack is a frequency counter to monitor the frequency output of the TQCM. The controller output is hardwired to the Helios for data recording.

For more discussion on TQCMs and our application see section 2.4.3.

2.3 Optical Train

Since the light sources for this experiment operate in the VUV, we must provide an evacuated path for the light. But to allow for a change in either source or optical filter there is a source mounting flange attached to the back left portion of the chamber where the source is attached. Figure 7 shows the essential features of the optical system.

2.3.1 RF Discharge Tubes

The source is an RF discharge tube supplied by Opthos Instruments. This is a sealed tube with a low pressure inert gas (we are currently using Krypton). The following table gives a listing of the wavelengths and tubes available from Opthos.

Table I. Resonance Tubes Available From Opthos

Lamp Type	Lines	Window
Hydrogen	1216 A	MgF ₂
Argon	1048 1066	LiF
Krypton	1165 1236	MgF ₂
Xenon	1296 1470	MgF ₂
Mercury	1849 2537	Suprasil
Iodine	several	Suprasil

The major output of the Krypton tube is at 1236 angstroms with some at 1165 angstroms and has a beam divergence of around 45 degrees full angle. According to the literature the tube should provide 10^{15} quanta/second or around 1.5 milliwatts total power. In all measurements so far we have not been starved for signal in the specular channel.

When using this tube the following procedure should get the arc going.

1. Turn on the cooling air supply line located above and behind the tube. Failure to supply cooling will break the tube.
2. While watching the gauges on the KIVA power supply slowly increase the power until the forward power (upper gauge) read slightly more than 10 watts. The backward power can read upwards to 20 watts.
3. Since this is an RF excited system we want to optimize the coupled energy to the RF cavity surrounding the neck of the discharge tube. To do this you slowly adjust the brass tuning screw on the cavity, located on the discharge tube, to minimize the backward power on the lower meter.
4. You now need to provide the cavity (this includes the gas in the tube) with a spark to start the discharge. This is done by "tickling" the tube with the tesla coil normally located on the shelf on the wall behind the vacuum chamber. You will only need to spark it a little to get it going, so if it doesn't strike right off don't rush it. If the discharge starts proceed to step 7.
5. If the discharge didn't strike in part 4 you may need to increase the forward power. You should never increase it above 20 watts.
6. If it still doesn't strike you can try tickling the tube while adjusting the cavity tuning. There is no chance for shock so don't be afraid of touching the brass RF cavity and its tuning screw.
7. After the arc is going I usually back the power down to 10 watts forward power and adjust the tuning screw for zero on the backward power.

You are now ready to illuminate your sample.

2.3.2 Collimating Apertures

There are two hard apertures in the system providing for simple collimation of the VUV light (see figure xx for location of these holes). These are co-aligned with the holes in the chopper wheel and provide a 5/16 inch diameter spot of light on the mirror. The holes are made from 1/8 inch aluminum plate drilled with ordinary drill bits. No effort was made to bevel the edges to provide scattering control at the holes.

2.3.3 Sample Mirror Mounts

The sample mirrors are mounted externally in a sample holder which is then screwed into the mirror stage in the vacuum chamber. This stage is fixed in angle and height and is thermally isolated from the base by ceramic standoffs. Proper indexing of the sample in orientation is accomplished by screwing the holder tightly up onto the copper sample mount. There is provision for a small adjustment in translation and angle by loosening the three bolts at the base of the sample mount and adjusting it by hand. There is no fine tuning adjustments since all fine tuning can be accomplished by the PMT detector mounts.

In addition temperature stability for the sample is provided by a coil of tubing that is soldered in hard contact with the sample mount. This tube is open to the outside to allow coolant flow from a refrigerated circulator or chilled water. This coolant is also routed to the TQCM heat sink to help regulate its temperature.

2.3.4 Detector Mounts

The three photomultiplier detectors are located as shown in figure 7. The three are labeled 1, 2 and 3 for back scatter, specular and forward scatter channels, respectively.

Each PMT mount is a 5 degree of freedom mount consisting of a set of three Newport Research Corp translation stages to provide x, y and z control and two rotation stages for azimuth and elevation control. There is also a grounded four inch long aluminum baffle cylinder with a 1/2 inch acceptance hole attached to the front part of each photomultiplier. This baffle cuts down on directly scattered light.

2.3.5 Detectors

There are three detectors for measuring reflectivity off sample surfaces. These detectors are arranged coplaner with the incoming UV light but are arrayed to measure the back scattered light, specular reflected light and the forward scattered light (see figure 7).

See Section 2.2.5 for a discussion of the photomultipliers used as detectors in this experiment.

2.4 Contamination Subsystem

The contamination subsystem provides the experimenter with a controllable way to deposit material onto a sample mirror.

The subsystem consists of a heat source in contact with the material to be evaporated and a device (TQCM) to measure the material deposited onto the sample. The subsystem is instrumented with thermocouples to monitor the temperatures at various places in the experiment.

2.4.1 Contaminant Mount and Heat Source

The contaminant is loaded into the chamber by clamping the material onto a vertically mounted aluminum plate soldered to a resistance heater (a simple enclosed heater wire). The heater is controlled by a variac source externally located on top of the KIVA power supply (left side of table under the chamber). The mount has one thermocouple attached to provide evaporation source temperature readings. This thermocouple is wired into the Helios for data recording.

2.4.2 Sample and TQCM Mount Cooling System

The sample and TQCM are maintained at a constant by the use of an external coolant source. The coolant is delivered through a liquid feedthrough located on the right side middle of the vacuum chamber. The copper delivery tube is soldered to the sample mount and to the TQCM heat sink and is thermally isolated from the remainder of the chamber by ceramic standoffs and by the vacuum in the chamber. Coolant can be either gas or liquid. Currently a refrigerated recirculator is attached to provide both coolant flow and temperature control.

A thermocouple is attached to the sample mount and is wired to the Helios for data recording.

2.4.3 Temperature Quartz Crystal Monitor (TQCM)

The use of quartz crystal microbalance (QCM) is a well established method for weighing thin films of materials that deposit on a surface in the solid state. Solid films couple strongly into the oscillating QCM and its frequency change is proportional to the mass loading. Controlling the temperature allows the device to operate below the ambient environment and increase the loading efficiency from the vapor phase.

The mass sensor is a precision matched set of 10 or 15 Mhz quartz crystals, one being the sensor and the other the reference. The output frequency of the TQCM is the beat frequency between the two crystals. By using the beat frequency, changes in frequency caused by ambient temperature variations is eliminated. Because only the sensor crystal sees the contamination flux, the TQCM output frequency will increase with mass loading, m , and for a 15 Mhz crystal.

$$m = 1.56 \times 10^{-9} \text{ g/cm}^2 \text{ hz}$$

For a detailed discussion of TQCMs see the engineering report provided by Faraday Laboratories in the storage cabinet.

In our application the TQCM is located directly above the sample mount (see figure 7) staring at the evaporation plate (approx. 4 inches away). With proper cooling the evaporated material condenses out on the TQCM and since the device is close to the sample mirror (approx. 2.5 inches) we get a good reading of the mass deposited onto the sample.

2.5 Data Acquisition

The data acquisition system, shown in figure 11, consists of an IBM AT compatible computer for control and storage, connected to a Helios II computer front end for the actual acquiring and communication functions. Also included is a commercial software package (Labatech Notebook) to provide communication control between the computer, the front end and the individual pieces of hardware.

2.5.1 Telex AT Compatible Computer

The Telex computer is an IBM AT clone with a forty megabyte hard disk, 640 kilobyte ram, single 5 1/4 inch floppy disk drive, 384 kilobyte extended ram and a color monitor with EGA driver card.

The system uses the first serial port and an RS232 null modem cable to communicate with the Helios front end. Using the software package in conjunction with the computer front end, tens of data channels can be acquired at close to one hertz dat rate.

2.5.2 Helios II Computer Front End

The Helios II computer front end is manufactured by Fluke Instruments as a go between the computer and data generating devices such as thermocouples, dc voltage sources, etc. The Helios contains A/D and D/A boards, frequency counters and a thermocouple controller board, among other input boards, to convert the raw analog data to a form to be transferred to the computer's display and storage.

Currently we have the following data channels wired into the Helios;

- Three PMT outputs
- TQCM frequency

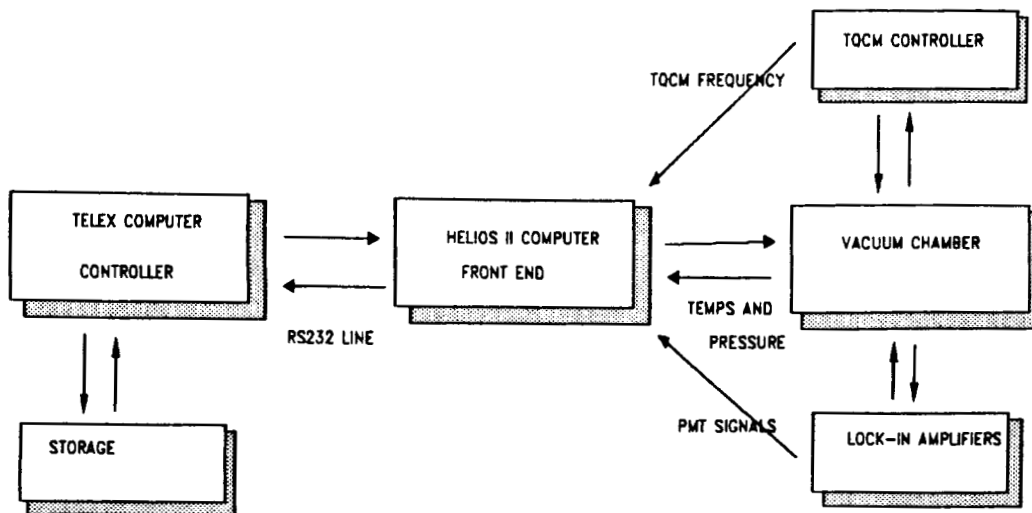


Figure 10 Data Acquisition System

- Evap source thermocouple
- Sample thermocouple
- Chamber pressure

2.5.3 Software

The data acquisition system uses two major pieces of software in its task. One is the Labtech Notebook and the second is Lotus 123. The first is for acquisition and storage and the second is for replay. Labtech Notebook produces files that are in a format that is importable to Lotus.

3.0 GETTING STARTED

This section will take you through the procedures required to bring up all the various subsystems. After running through all the following steps, you should be able to take data on a surface of choice using a contamination source and be able to store and retrieve the resulting data.

3.1 Starting with the chamber at atmospheric pressure.

This section assumes you are starting with either the chamber open to atmosphere or that the chamber has been under vacuum and you have replaced the sample or contamination source.

To start up follow the following steps;

I. Rough Pump the Chamber

1. Fill the liquid nitrogen (LN2) traps.
2. With the gate valve between the chamber and the roughing pump closed rough out the LN2 trap by opening the hand operated roughing valve located under the chamber at the red rubber hose.
3. Once the traps are pumped out close the roughing valve.
4. Open the large gate valve under the chamber. This opens the chamber to the LN2 trap.
5. Slowly open the roughing valve. This will open the system to the roughing pump and you will hear the pump start to gurgle and produce oil smoke. This should last only a few minutes as the large chamber is pumped out.
6. Pump out the chamber until you reach about 10 millitorr pressure or better on the gauge located atop the electronics rack. This can sometimes take several hours and shouldn't be rushed.
7. Once the pressure has reached the correct level you can close the gate valve shutting off the roughing pump. This valve sometimes doesn't close so make sure it does before moving to the next step.

II. Cryopump the Chamber

1. Open the gate valve to the cryopump. Be sure that the roughing valve is closed.
2. The wait for the system to pump down to the operating pressure of $<10^{-6}$ torr can sometimes take several days depending on how long the chamber has been open and what has been in it.

You are now ready to fire up the rest of the system. To turn on the system at this point follow the directions for "Starting from Vacuum Conditions" given below.

3.2 Starting from Vacuum Conditions

On a day to day situation you won't have the chamber open to the air, so you only need to concern yourself with the following steps.

- I. Turn on the computer. It takes a while to initialize.
- II. Turn on the water to the chopper. Without cooling the chopper will have heating problems in vacuum.
- III. Turn on the KIVA RF power supply. It typically takes 5 minutes for this supply to warm up and there is an interlock to keep the high voltage off until these five minutes have passed.
- IV. Turn on the equipment in the equipment rack.
 1. Turn on the three lock-ins. ~
 2. Switch on the Helios computer front end.
 3. Turn on the TQCM and the frequency counter.
 4. If you're using them turn on the oscilloscope and the HP pen plotter.
- V. Turn on water chiller and set to desired temperature.
- VI. Use the following procedure to turn on the illumination source.
 1. Turn on the cooling air supply line located above and behind the tube. Failure to supply cooling will break the tube.
 2. While watching the gauges on the KIVA power supply slowly increase the power until the forward power (upper gauge) read slightly more than 10 watts. The backward power can read upwards to 20 watts.
 3. Since this is an RF excited system we want to optimize the coupled energy to the RF cavity surrounding the neck of the discharge tube. To do this you slowly adjust the brass tuning screw on the cavity, located on the discharge tube, to minimize the backward power on the lower meter.
 4. You now need to provide the cavity (this includes the gas in the tube) with a spark to start the discharge. This is done by "tickling" the tube with the tesla coil normally located on the shelf on the wall behind the vacuum chamber. You will only need to spark it a little to get it going, so if it doesn't strike right

off don't rush it. If the discharge starts proceed to step 7.

5. If the discharge didn't strike in part 4 you may need to increase the forward power. You should never increase it above 20 watts.
6. If it still doesn't strike you can try tickling the tube while adjusting the cavity tuning. There is no chance for shock so don't be afraid of touching the brass RF cavity and its tuning screw.
7. After the arc is going I usually back the power down to 10 watts forward power and adjust the tuning screw for zero on the backward power.

VII. Turn on the main switch (located on the right of the control panel at the top of the equipment rack). You should ensure that the chopper is running by listening or by observing the sync signal on the scope or by waiting for the lock-ins to sync. This step could be done any time after water is turned on to the chopper motor.

VIII. Load the computer software.

1. Go to the directory on the computer where Labtech Notebook is located. Probably C:\NB
2. Insert the Labtech Notebook Key disk into drive A.
3. If you are in DOS type "NB" enter. This will load the interactive environment of Labtech Notebook.
If you are in a DOS shell (Pathminder, 1DIR, etc.) use its particular method to run the file NB.EXE.
4. The menus are currently set up to acquire data for two and on half hours and take five channels of data.
 - Specular signal
 - TQCM frequency
 - Chamber pressure
 - Evaporation source temperature
 - Sample temperature

To change any data channels refer to the documentation on Labtech Notebook.

5. Before you run the program be sure to go to the "FILES" menu and change the file you will be writing to. If you don't change this, you will write over the previous data run.
6. Run the program. It will wait for you to hit a key before actually taking data.

IX. Turn on the photomultipliers. Use the left switch on the control panel. You should see a signal on whichever lock-in corresponds to the PMT that is powered. To select a different PMT use the following procedure.

1. Turn off the photomultipliers. This turns off the high voltage power supply.
 2. Switch to another PMT on the high voltage switches located on the table at the lower left of the chamber. Remember that there is normally high voltage through these switches so be sure the power is off. Only one PMT will work with the power supply so be sure that only one is selected at the high voltage switches.
 3. Turn on the photomultipliers at the control panel. This returns high voltage so be careful.
 4. Remember that the software thinks you are recording the specular channel so you will need to change that in Labtec Notebook
- X. If you have a signal you can now either start the data acquisition by queuing the computer or by recording the output on the pen recorder.

XI. Good luck!

To turn off the system perform the steps in reverse order following these rules:

- Turn off the PMTs to remove high voltage
- Turn off the high voltage to the discharge tube early to allow the tube to cool down before you turn off the cooling air supply
- Don't forget the water supply to the chopper and the air supply to the discharge tube
- Be sure to park the hard drive using HDPARK before turning off the computer

4.0 WHERE TO FIND HELP.

This section will be devoted entirely to contacts to call when you've tried everything and have had no luck. Not all system components will have information in this section so feel free to contact me through UAH for any questions.

4.1 Cryopump

The cryopump is manufactured by

Varian Associates
Industrial Components Division
3100 Jay Street
Santa Clara, California 95054
Toll Free # 1-800-227-9722

It is a Cryostack 8 Cryopump, Serial # K3F4060. For information concerning the regeneration or other maintenance on this pump, see the manual kept in the file cabinet next to the phone in room E114 or look in the cryopump section in part II of this manual.

4.2 Photomultipliers

The photomultipliers are solar blind tubes furnished by

EMR Photoelectric
Box 44
Princeton, New Jersey 08542
phone 609-799-1000

I have had great luck with questions directed to EMR. Their marketing person is Mr. Dan Lister and their technical person is Mr. Steve Meddaugh.

Our tubes are type 541F-09-xx-xx with the following serial numbers;

1. #23248 purchased Aug 1978
2. #28229 purchased Apr 1980
3. #28230 purchased Sept 1980

The high voltage supplies were provided with the original tubes but they currently sell for around \$4800 whereas the PMT's sell for around \$4200 each.

4.3 PMT High Voltage Supplies

The vacuum compatible high voltage supplies for the photomultipliers are manufactured by EMR Photoelectric but

there is a cheaper source for identical supplies. This information was supplied by Mr. Dan Lister of EMR. Vacuum compatible supplies costing approximately \$1200 can be had from the following;

Research Support Instruments, Inc.
10610 Beaver Dam Road
Cockeysville, Maryland 21030-2288
phone 301-785-6250

The contact for technical and marketing information is also the company president. His name is Bob Crabbs and is a good source of information.

4.4 Discharge Tubes

The VUV source is an RF excited Krypton filled low pressure discharge tube supplied by the following;

Ophos Instruments, Inc.
17805 Caddy Drive
Rockville, Maryland 20855
phone 301-926-0589

This is a company run by an individual, Dr. Joe Reader who works at another job full time and runs this company as a side-line. To get help you must call and leave a message with the secretary (who knows no technical information) who will then pass the message to Dr. Reader and will call back with the now second hand answers. All this appears to work because they have managed to answer my questions satisfactorily. This company also supplies the KIVA power supply that feeds the RF to the discharge tube.